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Use of Jebel Marra Natural Pozzolana as a Replacement Material in Production of Low Cost Blended Cement

إستخدام البوزولانا الطبيعية بجبل مرة مادة بديلة
فى إنتاج الأسمنت المخلوط قليل التكلفة

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بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ

ن وَالْقَلَمِ وَمَا يَسْطُرُوْنَ اَوْنَتَا(1) بِنِعْمَةِ رَبِّكَ بِمَجْنُونٍ و(2) اِنَّ لَكَ
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ABSTRACT

The need for low cost natural materials to be used as supplementary material in blended cement, and concrete in rural areas of Sudan, and especially in Darfur, was the main reason for carrying out this study. The study mainly focuses on characterization of the locally available natural pozzolanic materials and their utilization in low cost cement, to facilitate shift from pure Portland cement which can be used in low cost concrete blocks, mortar, concrete and plaster

In this research samples of Volcanic ash materials from Jebel Maraa, were taken namely from Nyertity (NVA), Melem (MVA) Tina (TVA) and Kotrum (KTVA), and evaluate their efficiency as supplementary cementitious materials to Portland cement. Each material was characterized for its chemical and physical properties, using various techniques. Then they were used to prepare different blends using different substitution levels such as 10, 20 and 30% the blended were tested to determine their compliance with Standards. A replace mix of pure O.P.C was also prepared and tested to compare blends with it. The potential use of these materials to facilitate the shift from pure Portland cement to blended cement in mortar, concrete and concrete hollow blocks was then investigated.

The chemical and physical analysis of the samples showed that they are congruent with other materials used as supplementary materials, around the world. In physical analysis results, including standard consistencies and setting times for all blends, showed an increase in water demand with increasing substitution level. The results also indicated that addition of these pozzolanic materials retarded the setting, however this retardation was negligible and was within the limitations. The reactivity of volcanic ash was found to be within the limit of standards. The strength activity indexes of the pozzolanic materials were found to be 113% for NVA, 98% for MVA, 105% for TVA and 110% for KTVA, compared with the requirement of 75% and 80% specified by ASTM C-618 and Indian standard IS: 1344, respectively.

Result of permeability of blended cement in mortar showed that increasing the level of substitution decreases the permeability. Results of compressive strength of blended cements showed that, in general, increasing the level of substitution contributed to a reduction in compressive strengths. This is especially noticeable at early ages and for higher (greater than 20%) substitution levels. All blended cements showed a trend for increasing strengths with time, with the increase from 7 to 28 days greater than the increase from 28 to 90 days for 20% or less substitution levels. The optimum substitution level obtained from the compressive strength and confirmed by normalized compressive strength,

was therefore 20% for volcanic ash in concrete and matching with previous studies. The 30% substitution, despite resulting in strength reduction, gave acceptable strength values according to standards. Blended cement with 30% substitution level was used successfully in mortar and concrete hollow blocks. Accordingly the studies volcanic ash substitution can be safely used in reinforced concrete with 20% substitution level and in mortar and concrete hollow blocks using 30% substitution level. There substitution will greatly reduce the cost of cementing building materials. This was confirmed by comparing the cost of a typical house built with OPC and blended cement of 30% replacement, where they were used for blockwork (mortar), plastering and block production. The reduction found to be about 22%.

Furthermore chemical analysis and resulting calculation of mineralogical composition of blended cement at 20% replacement showed that these blends are identical to type I cement (OPC) and close to type IV cement (low heat cement).

مستخلص

لقد كان الدافع الأساسي لإجراء هذه الدراسة هو الحاجة لمواد طبيعية قليلة التكلفة يمكن ان تستخدم كمواد مضافة لانتاج اسمنت قليل التكلفة وبالتالي يمكن استخدامه في الخرسانة والبناء خاصة في مناطق السودان الريفية كدارفور مثلاً. لذلك فان هذه الدراسة تركز أساسا على خصائص المواد البوزولانية المتوفرة محلياً والاستفادة منها في خفض تكلفة الاسمنت وذلك بخلطها بالاسمنت العادي لانتاج اسمنت مخلوط، الشي الذي يؤدي الي التحول من الأسمنت البورتلاندي العادي إلى الأسمنت المخلوط (الاسمنت البورتلاندي البوزولاني) والذي يمكن ان يستخدم في الخرسانة وفي انتاج طوب البلك الخرساني وفي المونة والبياض.

في هذا البحث تمت دراسة الرماد البركاني من اربعة مناطق مختلفة في جبل مرة بغرب السودان هي نيرتتي (NVA)، الملم (MVA)، تينة (TVA) و كتروم (KTVA) وذلك بغرض تقييم فعاليتها كمواد مضافة للاسمنت البورتلاندي. وقد تم تحديد الخواص الكيميائية و الفيزيائية لكل مادة، وذلك باستخدام تقنيات مختلفة ومن ثم تم استخدام هذه المواد في إعداد خلطات باستخدام نسب إحلال 10% و 20% و 30% للاسمنت البورتلاندي وأجريت عليها عدة إختبارات لتحديد مدى مطابقتها للمواصفات. كما تمت دراسة إمكانية استخدام هذه الخلطات كمواد بديلة للاسمنت في المونة والخرسانة و في صناعة الطوب البلك.

أظهرت نتائج الاختبارات الكيميائية و الفيزيائية لهذه المواد مطابقتها للمواد البوزولانية الاخري الموجودة والمستخدمة حول العالم. وقد اظهرت نتائج الاختبارات الفيزيائية لكل الخلطات كالقوام القياسي وزمن الشك الابتدائي والنهائي زيادة في نسبة الماء للاسمنت كلما زادت نسبة إحلال البوزولانا للاسمنت وتأخير في زمن الشك لكن في الحدود المسموح بها في المواصفات. كما ان معامل الفاعلية البوزولانية مع الاسمنت أعطي نسبة 113% للرماد البركاني لنيرتتي، 98% للملم، 105% لتينة و 110% مقابل 75% و 80% النسبة القياسية الأقل المطلوبة في المواصفة الامريكية والهندية علي التوالي.

أظهرت نتائج قياس النفاذية للمونة الأسمنتية انه كلما زادت نسبة الإحلال كلما قلت النفاذية ، وايضا أظهرت نتائج قوة الانضغاط للأسمنت المخلوط ، بصفة عامة، انه كلما زادت نسبة احلال البوزولانا للاسمنت كلما قلت مقاومة الانضغاط ، خاصة عند فترة الانضاج المبكر ومستويات الاحلال العالية (اكبر من 20%) كما ان جميع الخلطات اظهرت زيادة في قوة الاتضغاط مع مرور الزمن ، بمعدل زيادة في عمر 7-28 يوم أكبر من معدل الزيادة في فترة الانضاج 28-90 يوما لكل نسب الاحلال. وبما أن إحلال 20% من الاسمنت بالرماد البركاني اعطي اعلى مقاومة مطابقة للمواصفات فإن نسبة إحلال البوزولانا المثلي للاسمنت من خلال نتائج مقاومة الانضغاط هي 20% للرماد البركاني. ولذلك تم استخدام نسبة 20% رماد بركاني بنجاح في انتاج الخرسانة المسلحة. وان نسبة الإحلال 30% وبالرغم من انقاصها للمقاومة، فانها تنتج مقاومة مقبولة وفقا للمواصفات ولذلك تم استخدامها في انتاج المونة و الطوب البلك الخرساني المفرغ.

عليه يمكن الاستنتاج من النتائج أن الاسمنت المخلوط بالبوزولانا الطبيعية المستخرجة من منطقة جبل مرة يمكن إنتاجه واستخدامه في المونة والخرسانة والطوب البلك حسب نوع الاستخدام النهائي. اذ يمكن استخدام الرماد البركاني مع نسب احلال حتي 20% في الخرسانة المسلحة ونسبة احلال 30% في المونة و الطوب البلك الخرساني هذه النسب من الاحلال ستخفض كثيراً من تكلفة المواد الاسمنتية المستخدمة في المباني وهذا ما اكدته دراسة اجريت على تكلفة مبنى او منزل نموذجي تم بناؤه من الاسمنت المخلوط (بنسبة 30%) مقارنة بالاسمنت العادي حيث استخدم الأسمنت بنوعيه في المباني (المونة والبياض) وفي انتاج البلكات الخرسانية وقد وجد ان نسبة الانخفاض في التكلفة بلغت حوالي 22%.

اضافة الى ذلك فان التحليل الكيميائي للاسمنت المخلوط والذي منه تم تحديد مكوناته المعدنية اثبت ان الاسمنت المخلوط بنسبة 20% يتطابق مع النوع الاول من الاسمنت (الاسمنت العادى (OPC Type I) ويقارب النوع الرابع (الاسمنت قليل الحرارة Type IV)

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LIST OF ABBREVIATIONS AND SYMBOLS

Agr	Agriculture Pozzolana: Sugar Cane and Wheat
Al ₂ O ₃	Aluminum oxide
ASTM	American Society of Testing and Materials
AR	Alumina Ratio
BCS	Black Cotton Soil Pozzolana
BCh	Before Christ
BDNP	Bayouda Desert Natural Pozzolana
BGSA	Bambraa Groundnut shell Ash
BoQ	Bill of Quantity
BS	British Standard
C-A-H	Calcium Aluminum Hydrate
C ₂ S	Dicalcium silicate
C ₃ A	Tricalcium Aluminate
C ₃ S	Tricalcium silicate
C ₄ AF	Tetracalcium Alumino ferrite
CH	Calcium Hydroxide
C-S-H	Calcium Silicate Hydrate
C&S	Clay & Shell Pozzolana
Dia	Diatomaceous earth

E	East direction
Eng	Engineering
EN	European Norms
gm	Gramme
GRAS	Geological Research Authority of the Sudan
HCC	High Cement Content
HLP	High Lime Pozzolana
in	Inch
IS	Indian Standard
K ₂ O	Potassium oxide
KTVA	Kotraoum Volcanic ash
LSF	Lime Saturation Factor
LOI	Loss on ignition
LPC	Lime Pozzolana Cement
LPB	Lime Pozzolna Binder
MgO	Magnesium oxide
MK	Metakaolin
MTE-CSA	Materials Test Engineering Concrete, Soil, Asphalt Test
MVA	Melem Volcanic ash
Na ₂ O	Sodium oxide
NP	Natural Pozzolana
NVA	Nyertiti Volcanic ash
OPC	Ordinary Portland Cement
PFA	Pulverized Fuel Ash
PKS	Palm Kernel Shell
P ₂ O ₅	Phosphorus pent oxide
SF	Silica Fume
SG	Specific Gravity
SiO ₂	Silicon dioxide
SNP	Sudanes Natural Pozzolana
SO ₃	Sulfur trioxide
SUST-CL	Concrete Laboratory Sudan University of Science & Technology
SUST-SL	Soil Laboratory Sudan University of Science & Technology
Sq	Square
SR	Silica Ratio
SSB	Stabilized Soil Block
TiO ₂	Titanium dioxide
TVA	Tina Volcanic ash
UK	United Kingdom
UNCHS	United Nations Center for Human Settlement
UPV	Ultra Pluse Velocity
VA	Volcanic Ash
W	West direction
µm	Micro meter

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